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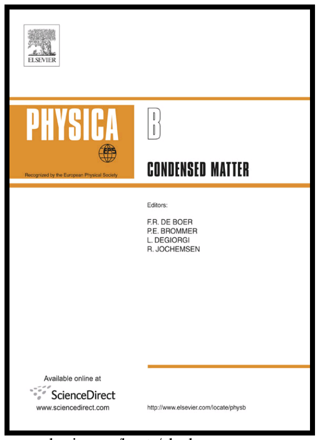

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Superparamagnetic Behavior of Antiferromagnetic Six Lines Ferrihydrite Nanoparticles

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Magnetic behavior of 5 nm antiferromagnetic six lines ferrihydrite particles is reported. The magnetization as a function of applied magnetic field data at 100 K are fitted to the modified Langevin function without and with considering a distribution in particle magnetic moment covering different ranges of applied magnetic field strength. The resulting fit parameters are analyzed and compared. In the first case fit parameters are found to be strongly dependent on the strength of applied magnetic field. But the fit parameters are found to be independent of applied magnetic field strength in the later case.

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I. INTRODUCTION

Since the pioneering work of Jacobs and Bean and Néel, behavior of small particles of different magnetic materials have been gaining the interest of researchers working in the area[1,2]. These systems also have many useful technological applications[3]. Properties such as superparamagnetism is only shown by these systems. In recent decades, works on antiferromagnetic nanoparticles also gained attention in addition to already much popular ferro and ferrimagnetic nanoparticle systems.

Ferrihydrite, a nanocrystalline material, is antiferromagnetic in nature[4]. Different environmental, biological and soil systems contain this material[5]. Large scale occurrence of ferrihydrite is in mines as an iron ore. However, identification of ferrihydrite in different natural systems is often difficult mainly due to low crystallinity and small particle size[6]. This material can also be synthesized by suitable chemical methods in laboratory. Ferrihydrite is mainly found in two stable phases. Depending on degree of crystallization, this compound has either two or six peaks in x-ray diffraction pattern and accordingly called as two or six lines ferrihydrite nanoparticles[7]. There are lots of reports on possible crystal structure of ferrihydrite but the correct crystal structure of this material is still disputed[8–10].

There are many works on synthesis and characterization of two lines ferrihydrite nanoparticles[4,11–16]. We also reported works on this system[17,18]. However there are only limited works on the six lines ferrihydrite nanoparticles[6,19]. This motivated us to study the magnetic behavior of this system. In this work, we study effect of applied magnetic field strength on magnetization process of 5 nm six lines ferrihydrite particles.

II. EXPERIMENTAL DETAILS

Six lines ferrihydrite nanoparticles are synthesized by the coprecipitation method. The details of this method are given elsewhere[19]. Briefly, Iron (III) nitrate is added to pre-heated distilled water under continuous stirring at 75 ^{0}C. This 0.025 M solution is kept as such for 20 minutes and then allowed to cool at room temperature for 15 minutes. After this, the glass beaker containing the solution is immersed in an ice bath for 15 minutes. Now, a 0.025 M aqueous solution of sodium hydroxide is added drop wise in the resulting solution at room temperature with continuous stirring till the pH of the system reaches 7.5. The resulting precipitate is washed several times with distilled water followed by oven drying at 45 ^{0}C and then ground to get a brown colored fine powder sample.

III. RESULTS AND DISCUSSION

A. Structural Characterization

X-ray diffraction is one of the properties shown by crystals. In this with decrease in size of crystal, the width of peak goes on increasing and vice-versa. Our dried powder sample is also characterized by x-ray diffraction pattern using PANalytical diffractometer. Diffraction data are collected using Cu K_α radiation at room temperature. This diffraction pattern obtained from synthetic ferrihydrite is shown in Fig. 1(a). From this figure we find that the synthesized sample is single phase six lines ferrihydrite[20]. This figure clearly shows five out of six expected x-ray diffraction peaks. Last two peaks are very close to each other and overlap due to finite broadening. Modified Scherrer formula is used to calculate the average crystallite size[21], which is found to be about 5 nm. Figure 1(b) shows transmission electron micrograph using a JEOL JEM 2100 transmission electron microscope working at 210 kV. From this micrograph, it is clear that the particles are of different shapes and sizes. The electron diffraction of the synthesized sample is shown in Fig. 1(c). This figure also shows five out of six rings corresponding to the x-ray diffraction peaks. Figure 1(d) shows histogram plotted by measuring the different sizes of particles obtained in transmission electron micrograph. This size distribution is found to be centered around 5 nm.